

Accommodating Rising Population in Rural Areas: The Case of Loudoun County, Virginia

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Washington, D.C., and Richmond, Virginia, are cities that share rich pasts in histories and politics. And although their centers lie 100 miles apart, the two areas also share something else—an approximately 12-mile-long border. According to the 2000 U.S. Census, the Washington, D.C., metropolitan statistical area (MSA) and the Richmond MSA literally bump into one another.

Although no one is likely to mistake the shared boundary area of the two MSAs for either city's downtown, MSAs have come to be the standard measure of a city's reach. That the two cities defined in this manner stretch well over 100 miles demonstrates the magnitude of population growth that has occurred in both urban areas. This growth is all the more impressive when one considers that much of it occurred in the last 30 years.

The rapid growth of suburban areas around Washington, D.C., and Richmond, Virginia (and of many cities like them), poses substantial challenges for both local elected officials and residents of those areas. These challenges include providing for housing, roads, sewers, schools, and the myriad requirements of a population spilling into formerly rural areas. Furthermore,

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because the Commonwealth of Virginia provides limited guidance to localities concerning growth, these questions often must be addressed by local officials.

The inability of localities to address growth in a more aggressive manner is guided by the so-called Dillon rule.¹ The Dillon rule is a legal principle—used in Virginia—that addresses whether certain powers lie with local governments. The rule possesses two features. The first states that local governments have three types of powers: in layman's terms, those granted expressly by the state, those strongly implied by the state, and those that are essential to localities. The second part of the Dillon rule states that if there is any reasonable doubt whether a power has been conferred on a local government, then the power has not been conferred. This second feature effectively limits the fiscal tools available to localities to those strictly allowed by the state.

Attempts by officials of some counties to gain additional fiscal powers to fund the infrastructure required for an increasing population have had limited success at the statehouse in Richmond. As a result, the "toolkit" available to localities is often lacking in mechanisms that could prove useful in designing efficient growth policies. Perhaps because their tools are limited by law, localities have had to rely on available approaches such as taxes on real property, zoning, and cash proffers from residential and commercial developers—policies they *can* utilize—to stem the pressures from a rising population.

Although property taxes and zoning are generally well understood policies, proffers are lesser known. In short, proffers are payments made by developers to local governments as a part of a zoning or rezoning process. State law dictates that proffers are voluntary. The payments of the proffers may assist in gaining local government approval of the zoning action, but the law is clear that a zoning decision cannot be denied solely because a developer refused to pay a specified proffer amount. State law also specifies that proffers are not impact fees, though in practice they effectively approximate the latter. That said, development already zoned without proffers cannot legally be required to offset any impacts and, even in zoning cases where proffers are involved, the amount may not correspond to impact costs.

Zoning and cash proffers policies are not always popular with residents and developers in suburban counties. For example, in Loudoun County, Virginia, a largely rural county west of Washington, D.C., local policies to address population growth have occasionally reached a fever pitch. At a 1999 public hearing on Loudoun's growth policies held at the county courthouse, newspaper accounts described a near riot, noting that police officers had to be brought in to control the crowd. The episode prompted Thomas Sowell, a noted economic columnist, to devote a column to the issues facing Loudoun that ran in newspapers across the nation. But the vigorous debate over increasing

¹ For a history and more detailed description of the Dillon rule, see Writ (1989).

population in the county has also been closely watched by a number of groups interested in growth issues and by surrounding counties, all of whom view Loudoun's debate as a guide to the likely direction of policy in general.

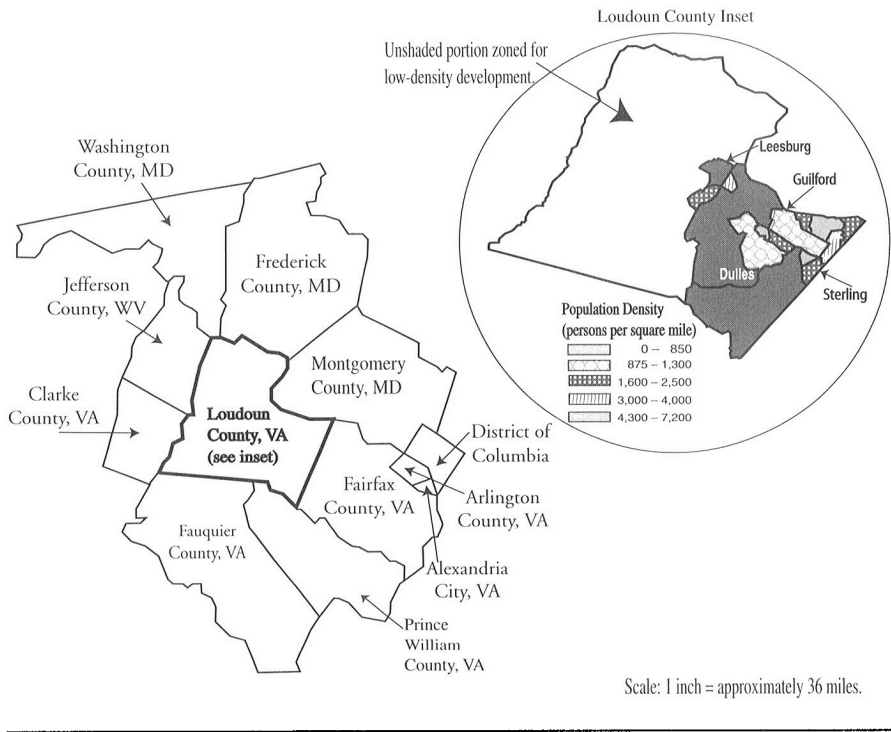
The Loudoun debate over population growth and how to address it is not surprising. Between 1990 and 2002, the county's population grew at a 7.5 percent annual rate, the second highest in the nation. But the rapid increase in the number of residents has not been welcomed by many in the county. County officials contend that the costs of infrastructure required to serve the population inflow exceeds the revenues generated, thus threatening the county's fiscal soundness (Meeting with Loudoun County Officials). In addition, incumbent residents complain that growth leads to more congestion. Yet there is less agreement as to the appropriate local policies to address the problems. Given the limited alternatives available, Loudoun officials have primarily adopted a zoning approach. Specifically, the county's board of supervisors has zoned the easternmost one-third of the county nearest Washington, D.C., (with the greatest population density) as residential, and it is available to accommodate additional population growth. In contrast, the westernmost two-thirds of the county (farthest from the downtown D.C. area) has been zoned for low-density development only, with allowable densities ranging from one household per 10 acres to one household per 50 acres (see Figure 1). These densities are so low that they effectively "shut the door" to new residential development in these areas of the county.

The situation in Loudoun raises many interesting questions concerning the effects of population growth on localities in the United States and in other industrial counties. Among the questions are, what kinds of impacts does population growth generate on county residents' welfare? Of the policies available to assist with the cost of population growth, which are used and why? And perhaps most important, are commonly used policies efficient in an economic sense?

The debate over these questions in Loudoun County, as in the broader debate, has been hampered by the lack of a formal model that identifies the likely relevant factors and traces out how they simultaneously affect residents' welfare. As a result, discussions between residents and local officials often isolate different arguments in an ad hoc manner, without providing a single coherent framework. The intent of this paper is to advance the debate by proposing a more formal treatment.

An examination of Loudoun's policies within a more formal setting may serve as a useful benchmark in analyzing the impact of rising population on counties. In particular, we will consider three responses to a rising population: zoning, raising the tax rate on real property, and using unrestricted proffers. We will discuss why these policies arise and explore whether they are efficient.

Figure 1 Population Densities in Loudoun County



To provide a framework in which these issues can be more systematically examined, this article presents a simple model of county agglomeration, inspired by Henderson (1987), where increases in population density lead to local congestion and higher prices for housing services. The model recognizes that opening a new area of a county to development entails substantial fixed costs linked to infrastructure construction and maintenance, such as sewage and water systems, highways, and schools, that are financed almost exclusively by local property taxes. Costs are fixed in the sense that opening an area to development requires a fixed amount of resources that is independent of the degree of residential development that takes place. Thus, an infrastructure network must typically be in place when an area is opened, irrespective of how many households actually move in. Under these conditions, we argue that localities' desire to maintain fiscal soundness combined with state legislated restrictions on their ability to raise revenues leaves them with little recourse outside zoning restrictions.

Since housing prices in a given region generally rise with population density, all else equal, opening new areas to residential development lowers the

average price of housing services as population spreads out across a larger area. The model then suggests that consumption of housing services generally rises but that the overall share of income devoted to housing remains unchanged, a result verified by data from Loudoun County. Hence, without sufficiently strong population growth, revenues from property taxes will fail to cover the additional cost of infrastructure associated with new residential developments. Indeed, Milligan (2003) argues that “one reason the Loudoun board used the blunt instrument of rezoning is because state lawmakers have resolutely refused to give localities other tools to manage growth.” In other words, without the ability to acquire additional funds by raising property tax rates, the fixed costs associated with infrastructure construction and maintenance naturally lead to inertia in the creation of new residential developments.²

Because our model contains both property taxes and congestion externalities, the decentralized equilibrium is potentially inefficient. Even so, we show that in so far as congestion externalities are mainly local in nature, the decentralized distribution of individuals across locations is socially optimal. The presence of property taxes, however, does distort the consumption of housing services relative to other types of consumption. We argue that the policy of charging a proffer per housing unit to developers, which some localities have effectively followed in Virginia, constitutes a less distortional means of financing the costs of public infrastructure. In our framework, the use of proffers can actually help implement the first best solution in a decentralized setting.

1. A MODEL OF COUNTY AGGLOMERATION

Consider a county that encompasses $S > 0$ areas, where $\mathcal{S} = \{1, 2, \dots, S\}$, can be thought of as a group of Census tracts. We let $\mathcal{M} = \{1, 2, \dots, M\} \subseteq \mathcal{S}$ denote the set of areas open to residential housing. To be equipped for residential settlement, a region $i \in \mathcal{M}$ with land area $A_i > 0$ requires that a complete infrastructure network be provided and maintained. Examples of infrastructure include roads, sewer and water systems, schools, and public transportation, which in aggregate is assumed to carry a fixed resource cost, $\Phi(A_i)$, with $\Phi(0) = 0$, and $\Phi'(A_i) > 0$.

For now, we assume a fixed county population N , with N_i individuals living in location $i \in \mathcal{M}$. Each individual is endowed with one unit of labor, which he provides inelastically in a core city located outside the county. The distance from any area $i \in \mathcal{S}$ to the city varies depending on its location within the county. In Loudoun, for example, the relatively large area of the

² Although Loudoun has the legal authority to assess taxes against real and personal property and to accept proffers on housing created by new rezoning actions, officials stress that pressure from residents of the county and from state-level legislators limit their ability to raise these taxes to levels that would cover the cost and operation of infrastructure. Furthermore, the addition of new debt by the county is constrained by any deterioration in the county's revenue-expense ratio. The county finance director states that a less favorable ratio reduces the county's debt rating.

county means that some residents live as close as 25 miles from the center of Washington, D.C., while other residents may live as far away as 50 miles.

Production

Individuals are employed in the production of a county-wide traded good summarized by,

$$y = \lambda \sum_{i=1}^M N_i, \quad \lambda > 0, \quad (1)$$

where y denotes the quantity of traded good output. These goods are produced competitively by firms that operate in the city center. Profit maximization by these firms immediately implies that

$$w_i = \lambda = w \quad \forall i, \quad (2)$$

where w_i is the wage paid to individuals living in area i . Since individuals living in different regions of the county are perfect substitutes in production, they all earn the same wage. In the model below, the distribution of individuals across county areas derives from a tradeoff between commuting costs and the cost of housing services. To the degree that different individuals have different incomes, this tradeoff would involve net commuting costs instead. In a setting with net commuting costs, however, the substance of our analysis would remain largely unchanged.

Individuals living in different areas of the county open to development also consume housing which we treat as a location-specific good. As in Chatterjee and Carlino (2001), this good is produced using a technology that is linear in the traded good. Specifically, we have that

$$G_i = (\gamma d_i^\eta)^{-1} x_i, \quad \gamma > 0, \quad \eta > 0, \quad (3)$$

where x_i represents the quantity of the traded good required to produce G_i units of the local good in region i . The variable d_i denotes population density in location i , N_i/A_i . Thus, the factor γd_i^η in equation (3) captures the notion that higher population density reduces the efficiency of local good production.

Local good producers, interpreted here as providers of housing services, operate in a competitive market and maximize profits,

$$\max p_i G_i - x_i, \quad (4)$$

where p_i is the price of the local good in region i in units of the traded good. These producers take population density in each county area as given. Substituting for x_i in equation (4), and maximizing with respect to G_i , the price of the local good in county area i will then reflect its marginal cost,

$$p_i = \gamma \left(\frac{N_i}{A_i} \right)^\eta. \quad (5)$$

Therefore, as population increases in location i , so does the price of housing services in that area.

Preferences

Individuals that live in county location i have linear preferences over an aggregate good, C_i , given by

$$C_i = [(1 - \delta_i)g_i]^\theta c_i^{1-\theta}, \quad (6)$$

where $0 < \theta < 1$ and $0 < \delta_i < 1 \forall i$. In equation (6), c_i and g_i represent consumption of the traded and local good, respectively. Since g_i represents housing services, individuals consuming g_i can be thought of as renters. The parameter δ_i captures the reduction in utility imposed by commuting between home and work. We can think of this reduction in the following way. Suppose two identical houses differ only in how far they are located from the workplace at the city center. A resident living at the more distant house spends more time commuting and correspondingly spends less time at home, thus getting less satisfaction (i.e., a higher δ_i) from a given amount of housing services. It is worth noting, though, that distance from the city center is not the only source of differences in commuting times. In practice, the location of roads, bridges, mountains, and physical features generally affect commuting times. Thus, it is entirely possible to find locations nearer to the city center that actually have longer commuting times to the city core. As a general rule, however, we expect that differences in housing services consumption will reflect the distance from the city center and the associated commute costs.

Each individual living in location i faces the following budget constraint,

$$p_i g_i + c_i \leq w - \tau p_i g_i, \quad (7)$$

where τ is a county-wide property tax that helps cover the cost of public infrastructure in areas open to development. In Loudoun County, the total real property and personal taxes collected each year amounts to \$400 million, the approximate cost of operating the county's school system. Utility maximization subject to constraint (7) implies that a mobile individual residing in location i chooses

$$g_i = \frac{\theta w}{(1 + \tau)p_i} \quad (8)$$

and

$$c_i = (1 - \theta)w. \quad (9)$$

Equilibrium

We focus on equilibria where the distribution of individuals across county locations leaves no region open to development unoccupied. From equations

(3) and (9), the indirect utility achieved by an individual living in location i is,

$$\mathcal{V}_i = \theta^\theta (1 - \theta)^\theta (1 - \delta_i)^\theta (1 + \tau)^{-\theta} p_i^{-\theta} w, \quad (10)$$

or, substituting for p_i and w ,

$$\mathcal{V}_i = \theta^\theta (1 - \theta)^\theta (1 - \delta_i)^\theta (1 + \tau)^{-\theta} \gamma^{-\theta} \left(\frac{N_i}{A_i} \right)^{-\theta \eta} \lambda. \quad (11)$$

Equilibrium with free movement of individuals requires that utility be equalized across all locations, $\mathcal{V}_i = \bar{\mathcal{V}} \forall i \in \mathcal{M}$. If there were a pair of locations i and j with $\mathcal{V}_i > \mathcal{V}_j$, individuals would seek to move from j to i . This would raise congestion in i and lower it in j until \mathcal{V}_i and \mathcal{V}_j were equalized. In addition, the sum of individuals across locations open to development must equal the exogenous county-wide population,

$$\sum_{i=1}^M N_i = N. \quad (12)$$

Finally, the county must cover the fixed costs associated with providing and maintaining public infrastructure in the developed areas,

$$\sum_{i=1}^M N_i \tau p_i g_i = \sum_{i=1}^M \Phi(A_i), \quad (13)$$

where the left-hand side of the above expression denotes tax revenues from property taxes.

Proposition:

Under the maintained hypotheses, there exists a unique distribution of individuals across open locations, N_i , $i = 1, \dots, M$, with common utility, $\bar{\mathcal{V}} > 0$.

Proof:

Observe that the conditions $\mathcal{V}_i = \bar{\mathcal{V}} \forall i \in \mathcal{M}$ and $\sum_{i=1}^M N_i = N$ make up $M + 1$ equations in $M + 1$ unknowns, namely N_i , $i = 1, \dots, M$, and $\bar{\mathcal{V}}$. Thus, rewrite equation (11) as

$$N_i = \left[\frac{\bar{\mathcal{V}}}{\theta^\theta (1 - \theta)^\theta (1 - \delta_i)^\theta (1 + \tau)^{-\theta} \gamma^{-\theta} \lambda} \right]^{-\frac{1}{\theta \eta}} A_i.$$

Substituting this expression into equation (12), it follows that $\bar{\mathcal{V}}$ must solve

$$\sum_{i=1}^M \left[\frac{\bar{\mathcal{V}}}{\theta^\theta (1 - \theta)^\theta (1 - \delta_i)^\theta (1 + \tau)^{-\theta} \gamma^{-\theta} \lambda} \right]^{-\frac{1}{\theta \eta}} A_i = N.$$

Define the left-hand side of the above expression as $F(\bar{\mathcal{V}})$, and note that $\lim_{\bar{\mathcal{V}} \rightarrow 0} F(\bar{\mathcal{V}}) = \infty$ while $\lim_{\bar{\mathcal{V}} \rightarrow \infty} F(\bar{\mathcal{V}}) = 0$. Since $F(\bar{\mathcal{V}})$ is continuous, by

the Intermediate Value Theorem, there exists $\bar{\mathcal{V}} > 0$ such that $F(\bar{\mathcal{V}}) = N$. In addition, because $F(\bar{\mathcal{V}})$ is strictly decreasing in $\bar{\mathcal{V}}$ on $[0, \infty)$, this solution is unique.

Given the solution for $\bar{\mathcal{V}}$, one can then simply solve for the distribution of individuals across location using (11).

The model of county agglomeration we have just presented possesses two important features that emerge as equilibrium outcomes.

First, the relative price of housing services between any two county areas reflects differences in commuting costs. In particular, from equation (10), the condition that $\mathcal{V}_i = \mathcal{V}_j$ for any two areas open to residential housing implies that

$$p_i = p_j \left(\frac{1 - \delta_i}{1 - \delta_j} \right) \quad \forall i \text{ and } j \in \mathcal{M}. \quad (14)$$

In other words, in choosing where to live within the county, individuals will trade off the price of housing services against commuting costs. In particular, county locations that involve a shorter commute to work will tend to have higher-priced housing services. In fact, this result appears to hold in Loudoun, though the heterogeneity of the housing stock makes a precise measure difficult. According to county officials, identical houses in areas with lower commuting costs generally command higher prices (and thus rents) than similar houses in areas of the county with higher commuting costs.

Second, because prices of housing services reflect congestion externalities driven by higher density, county areas with higher commuting costs will also have lower densities. In (14), $\delta_i < \delta_j$ implies that $p_i > p_j$. By equation (5), we then also have that $d_i > d_j$.

At this stage, we find it useful to introduce a numerical example to better highlight key features of our model as the economic environment changes. Specifically, given the debate surrounding Loudoun County, we focus on the effects of a rising county population as well as those of a change in the number of areas open to residential housing. We shall also use this numerical example below in making comparisons with the efficient solution.

Calibration to Current Loudoun County Benchmarks

According to our model, differences in commuting costs, δ_i , lead to varying densities in different regions. Therefore, as shown in Figure 1, we partition the developed eastern region of Loudoun County (i.e., the region unaffected by zoning restrictions) into density quintiles and set δ_i to match the density of each of the five areas. The associated five land areas have sizes, in square miles, 116.4, 27.3, 13.2, 8.2, and 5.7, and we calibrate A_i to match each of these land areas. The population density in these five areas are, in people per square mile, 208.21, 1,072.71, 1,909.00, 3,563.51, and 5,613.52. Observe in Figure 1 that low-density areas tend to be farther away from Fairfax County

Table 1 Model Parameters

Calibrated Benchmark Parameters		Value
Preferences		
θ	Housing share of income	0.25%
Technology		
λ	Per capita income	\$50,238
γ	Scalar in density congestion	93.41
η	Curvature in density congestion	0.49
Geography		
δ_i	Commuting costs	[0.09, 0.11, 0.14, 0.17, 0.23]
A_i	Land area (square miles)	[5.7, 8.2, 13.2, 27.3, 116.4]
N	Population	139,873

and Washington, D.C., where Loudoun County residents typically commute to work.

According to the U.S. Census, the population in the developed areas of Loudoun County currently stands at 139,873, and we set N to match this value. We choose λ to reflect an individual's yearly earnings in the county, \$50,238. This number reflects a weighted average of male and female full-time workers. From the Census, the share of income spent on housing and property taxes, θ , is approximately 0.25. It is difficult to get an accurate housing price per square foot corresponding to each region, where we think of square footage as a proxy for housing services. However, data from the Loudoun County Office of Mapping and Geographic Information suggests that \$143 per square foot is a reasonable upper bound for that county. We then choose γ to match this upper bound in equilibrium, $\gamma = 93.41$, and set η assuming a 15 percent gradient in housing prices from the most to the least dense area.

Finally, because individuals spend $p_i g_i$ of their yearly disposable income on housing services, current housing values, V , for the typical individual are given by

$$V = \phi (p_i g_i), \quad (15)$$

$$\phi = \frac{1}{r} \left[\frac{(1+r)^{T+1} - 1}{(1+r)^T} \right],$$

where ϕ is a factor that captures the present value of a one dollar annuity discounted over the number of years that a house provides services, T , and rate, r . In particular, given that the typical household contains 2.7 individuals in Loudoun County, our model suggests that the representative house is worth approximately \$435,000 when $T = 30$ and $r = 0.05$. Property tax rates in Loudoun County are currently set to 1.08 percent of housing values. Since

Table 2 Model and Data Statistics

Population Distribution	
Loudoun County	[24,227; 29,265; 25,226; 29,348; 31,807]
Model	[24,231; 29,238; 25,235; 29,375; 31,791]
Density Distribution	
Loudoun County	[208.21; 1,072.71; 1,909.35; 3,563.51; 5,613.52]
Model	[208.24; 1,071.79; 1,910.36; 3,569.32; 5,616.88]
Average Housing Prices	
Loudoun County	\$427,199
Model	\$435,279
Household Property Taxes	
Loudoun County	\$4,613.00
Model	\$4,701.00

the property tax in (7) applies to $p_i g_i$ rather than $\phi(n p_i g_i)$, where n is the number of individuals per household, we let $\tau = 0.0108\phi n$, or 0.18. This tax generates about \$4,700 per household yearly. The parameters that achieve our calibration targets are summarized in Table 1.

Table 2 reports the model-generated population and density distribution in each of the five areas depicted in Figure 1. As shown in the table, the model, although stylized, does well in reproducing actual Loudoun County statistics. In addition, we are also able to approximate statistics we had not explicitly targeted. For instance, both average housing prices and yearly property taxes collected per household conform relatively well to the data.

Zoning Restrictions in the Face of Increasing Population

The model above implies that in a given year, approximately \$243 million are collected in property taxes in the developed region of Loudoun County.³ Since this revenue is used exclusively to finance the provision and maintenance of public infrastructure, the corresponding fixed costs come to slightly more than \$1.42 million per square mile.

³ According to the 2000 Census, in total, Loudoun County collects \$300 million in real property taxes, approximately \$223 million of which, close to the model's prediction, comes from the eastern, developed portion of the county.

Suppose that local authorities were to consider lifting zoning restrictions on 10 additional square miles adjacent to the already developed part of the county. Because we assume this area to be immediately adjacent to the least dense populated region, we posit similar commuting costs, $\delta = 0.23$. Residents of the new area, therefore, would incur commuting costs equivalent to a 23 percent reduction in housing services. Moreover, according to our calculations, opening this region to development would require an additional \$14.2 million in property taxes.

With no population growth and no adjustment in property tax rates, our model implies that total property taxes collected would also remain unchanged. The existing population would spread out across a larger area thus lowering density and, by equation (5), local goods' prices. However, by equation (8), individuals would then increase their consumption of housing services so as to leave the share of income they spend on housing exactly unchanged. In practice, the share of income devoted to housing services is indeed nearly constant over time, not only in Loudoun County and Virginia, but nationally. Since this amount helps determine housing values in equation (15), it follows that these values would then remain unaffected and so would the resulting property taxes. Hence, opening a new area to residential housing is feasible only if the rate of net migration into the county is sufficient to generate tax revenues equal to the additional fixed costs incurred.

In our hypothetical example, the existing county population would have to increase by approximately 5.9 percent to yield an increase in the tax base large enough to generate an additional \$14.2 million. This represents an increase of around 8,250 individuals or 3,050 households. Thus, given that installing and maintaining infrastructure entails substantial fixed costs, our analysis implies inertia in the creation of new developments. That is, the population residing in areas already open to development has to reach a high enough threshold that the tax base can cover the additional cost of new infrastructure. Therefore, with legislated and/or political limits on a county's ability to raise property tax rates, local authorities have little practical recourse other than to appeal to low-density zoning restrictions. Note that while population grows to meet a threshold that would allow the county to open a new area, density increases, local goods prices rise, and consumption of housing services fall. Consumption of the aggregate good, C_i , in equation (6), therefore, decreases for the representative individual.⁴ It is no surprise, therefore, that some county residents complain of congestion and exert pressure on Loudoun County's board of supervisors to lift zoning restrictions.

It is important to note that given a fixed county population, N , opening a new area of the county to residential development in our framework does not necessarily increase welfare. On the one hand, the new area would allow for lower population density and lower congestion in existing regions of the

⁴ Recall that all individuals have the same utility in equilibrium, $C_i = C_j \forall i, j \in M$.

county. This effect induces individuals to consume more housing services which increases welfare. On the other hand, to the degree that the cost of additional infrastructure raises property tax rates, consumption of housing services would fall. On net, it is not clear that consumption of housing services would increase if an additional region of the county were zoned for residential settlement. Furthermore, from (6), commuting costs associated with the new area would also play a direct role in the evaluation of welfare.

In Loudoun County, rates of increase in the county's population are forecast to remain high, though not as high as in the 1990s. Loudoun's Department of Economic Development projects that the county's population will rise at an average annual rate of 4.7 percent over the next nine years, about triple the rate of population growth expected in the United States over the same period. Thus, it is likely that an imbalance between population growth, revenues, and infrastructure adequacy will continue to face the county.

2. THE SOCIAL PLANNER'S PROBLEM

We now show that the outcomes in the decentralized county economy are not Pareto optimal. Specifically, we can assess Pareto optimality by comparing our results above with the results from the same problem for a hypothetical social planner. Contrary to most models in regional economics, the source of inefficiency in our framework does not stem from the congestion externalities linked to density. In our model, these externalities are local in nature and, therefore, directly reflected in the price of housing services in the concerned region. In essence, the technology in (3) assumes that greater density in region i congests the production of housing services in that region, and not in another region that is further away.⁵ The population density distribution, therefore, replicates that which emerges in the decentralized equilibrium. The presence of county taxes, however, does distort the consumption of housing services relative to other types of consumption. We argue that local government should finance infrastructure by charging developers a lump sum proffer per housing unit rather than relying on property taxes. Some localities in Virginia charge proffers. We show that their approach can actually help implement the first best solution in the decentralized setting.

The social planner looks to maximize the utility of households in the county, as given by

$$\sum_{i=1}^M N_i [(1 - \delta_i) g_i]^\theta c_i^{1-\theta}. \quad (16)$$

⁵ This is also the case in Chatterjee and Carlino (2001).

The only constraints faced by the planner are the county's resource constraint,

$$\sum_{i=1}^M N_i c_i + \sum_{i=1}^M N_i x_i + \sum_{i=1}^M \Phi(A_i) = \lambda \sum_{i=1}^M N_i, \quad (17)$$

and the requirement that population in regions open to development add up to county population, (12). The middle term on the left-hand side of (17) captures the resource costs, in units of the traded good, associated with the county-wide provision of housing services, where x_i is implicitly defined by the technology in (3).

The planner's optimal choice of regional traded good consumption, c_i , local good consumption, g_i , and regional population, N_i , are respectively given by

$$(1 - \theta)[(1 - \delta_i)g_i]^\theta c_i^{-\theta} = \mu_2, \quad (18)$$

$$\theta[(1 - \delta_i)g_i]^{\theta-1} (1 - \delta_i)c_i^{1-\theta} = \mu_2 \gamma \left(\frac{N_i}{A_i}\right)^\eta, \quad (19)$$

and

$$[(1 - \delta_i)g_i]^\theta c_i^{1-\theta} + \mu_2 \left[\lambda - c_i - \gamma(1 + \eta) \left(\frac{N_i}{A_i}\right)^\eta g_i \right] - \mu_1 = 0, \quad (20)$$

where $\mu_1 \geq 0$ and $\mu_2 \geq 0$ are the Lagrange multipliers associated with constraints (12) and (17).

We now demonstrate that the planner's solution entails the same distribution of population across regions as that found in the decentralized equilibrium. To see this, observe first from (14) that the decentralized allocation of individuals across regions can be summarized by

$$(1 - \delta_j)\gamma^{-1} \left(\frac{N_j}{A_j}\right)^{-\eta} = (1 - \delta_i)\gamma^{-1} \left(\frac{N_i}{A_i}\right)^{-\eta} \quad \forall i \text{ and } j \in \mathcal{M}. \quad (21)$$

Under the optimal solution, we can use equations (18) and (19) to show that

$$(1 - \theta)\theta(1 - \delta_i)\gamma^{-1} \left(\frac{N_i}{A_i}\right)^{-\eta} = \mu_2^{\frac{1}{\theta}} \quad \forall i \in \mathcal{M}. \quad (22)$$

Since μ_2 is constant across regions, equation (22) implies (21), and the optimal allocation of individuals across locations replicates that of the decentralized equilibrium. Because in our model, congestion externalities reduce the production efficiency of housing services locally, individuals who move and congest a given region have to pay higher prices for housing services in that region. As in Chatterjee and Carlino (2001), the formulation of local externalities seems to us more reasonable than one where a region's density

decreases the production efficiency of housing services in another area that is potentially much further away.⁶

It remains that in the decentralized equilibrium, the presence of taxes on housing services distorts the allocation of consumption between the traded and local good. In our model, this distortion is small and results only in a 0.2 percent loss in welfare when measured in terms of the aggregate consumption basket, C_i . However, we now argue that allowing localities to charge developers a lump sum proffer to finance public infrastructure can help remove the distortion altogether.

Using Lump Sum Proffers as a Means to Finance Infrastructure

The main trouble with county taxes, as depicted in (7), is that they are proportional to housing services—and thus housing values—which leads to suboptimal decentralized allocations. In other words, individuals in every locality are led to consume less housing services than they otherwise would absent taxes. Historically, however, localities in Virginia have had the ability to accept voluntary lump sum cash proffers from residential developers, independent of the quantity of housing services they provide.⁷ The courts in Virginia have held that the absence of “voluntary” payments cannot be the sole reason for denying zoning or rezoning. However, many counties, including Loudoun, publicize the recommended proffers per residential housing unit constructed. In a setting where a new area is opened to development, all houses constructed would be subject to a lump sum proffer. In the case of opening a new area to housing, zoning, or rezoning action would be necessary so that proffers could apply to all housing.

We now show that, in the decentralized equilibrium, these proffers would simply be passed on to consumers, provided developers operate in a competitive market. More importantly, because they are non-distortionary, using these proffers in lieu of property taxes would allow the market equilibrium to replicate the social optimum.

Suppose that each county locality charges developers a cash proffer, Π_i , per housing unit that is unrelated to the amount of housing services they sell, G_i .⁸ In equilibrium, these cash proffers have to be such that $\sum_{i=1}^M N_i \Pi_i = \sum_{i=1}^M \Phi(A_i)$ to maintain the feasibility of areas open to development. Let

⁶ Note that the social optimum would yield population allocations different than those given by the decentralized equilibrium if congestion had an effect on commuting costs.

⁷ In practice, these proffers can only be raised following zoning or rezoning actions.

⁸ Observe that housing units can be of different sizes, our proxy for G_i . Furthermore, an implicit assumption here is that each individual requires one housing unit, although individuals can combine into households.

$R(G_i) = p_i G_i + \Lambda_i$ denote a developer's revenue from selling G_i units of housing services in locality i . Developers are assumed to operate in a competitive market, and we allow for any pricing rule that enables firms to charge both a price per unit of housing services, p_i , and a fixed amount, Λ_i , that could potentially be zero.⁹

From (3), a developer's profits in terms of the traded good are given by

$$R(G_i) - \gamma d_i^n G_i - \Pi_i. \quad (23)$$

It is then easy to see that the pricing rule whereby firms charge γd_i^n per unit of housing services and pass on the entire cash proffer to consumers constitutes a unique equilibrium pricing rule. First, to see why it is an equilibrium rule, observe that a firm with a pricing strategy such that $R(G_i) > \gamma d_i^n G_i + \Pi_i$ would have no customers. Other firms would be able to charge slightly less and capture the entire demand while still making at least zero profits. On the other hand, a pricing rule that yielded revenues less than $\gamma d_i^n G_i + \Pi_i$ would have the firm make negative profits and is not sustainable. Therefore, in equilibrium, firm revenues have to be exactly $\gamma d_i^n + \Pi_i$. Second, to see why $\{p_i, \Lambda_i\} = \{\gamma d_i^n, \Pi_i\} \forall i \in \mathcal{M}$ represents a *unique* equilibrium pricing rule, consider any other strategy, $\tilde{p}_i = \gamma d_i^n + \varepsilon$, $\varepsilon \geq 0$ and $\tilde{\Lambda}_i$. Because total revenue must be $\gamma d_i^n + \Pi_i$ in equilibrium, a firm that charges \tilde{p}_i per unit of housing services would have to adjust the fixed portion of its pricing strategy such that $\tilde{\Lambda}_i = \Pi_i - \varepsilon G_i$. But this contradicts the notion that $\tilde{\Lambda}_i$ is independent of G_i . Therefore, the rule whereby firms charge marginal cost per unit of housing services and pass on the entire cash proffer required by the county to individuals is the only equilibrium pricing rule.¹⁰

Of course, the main point here is that faced with this pricing rule, individuals' budget constraint (7) in the decentralized county economy becomes

$$(p_i g_i + \Lambda_i) + c_i \leq w. \quad (24)$$

Hence, their consumption of housing services is no longer distorted relative to other types of consumption, and the decentralized equilibrium can achieve the first best solution. Observe that while individuals pay more for housing services relative to the previous section, they no longer have to pay taxes on housing services. In fact, since all that matters in terms of providing county-wide infrastructure and its operation is that its costs be covered by cash proffers collected from developers, $\sum_{i=1}^M \Phi(A_i) = \sum_{i=1}^M N_i \Pi_i$, the county can design a regional distribution of proffers such that the difference between what individuals now pay for housing services and what they paid in the

⁹ Since our model is static and does not distinguish between housing stock built at different dates, we think of Λ_i as the yearly amount corresponding to the capitalized proffer value that a developer would be charged at the time of construction.

¹⁰ Observe also that any two-part pricing strategy that successfully attracts customers away from $\{p_i, \Lambda_i\} = \{\gamma d_i^n, \Pi_i\}$ necessarily yields negative profits.

previous section exactly equals what they were originally spending in property taxes, $\Lambda_i = \Pi_i = \tau p_i g_i$. There is no sense, therefore, in which this proffer-based policy would ultimately end up being more costly to individuals.

If proffers allow counties to offset the cost of infrastructure and its operation associated with new housing, why is zoning still used along with proffers in Loudoun County? The answer lies in the legal restrictions associated with proffers. Legally, proffers can be used to offset fully or partially only the capital costs of infrastructure, not operating costs. In the case of schools, for example, the operating cost is a substantial portion of the total cost, meaning that proffers will not overcome the fixed cost problem discussed earlier. Without the ability to use proffers to offset infrastructure costs fully, counties resort to zoning to limit the fiscal impact of rising population.

3. SUMMARY REMARKS

Rapidly increasing population in formerly rural counties on the fringe of urban areas has strained local governments' ability to provide infrastructure, raising congestion levels. The difficulty in providing adequate infrastructure lies in the fixed cost nature of infrastructure production as well as political and legal restrictions on localities' ability to raise revenue. Using a simple model of locational choice, we find that local officials could best balance population and infrastructure through a lump-sum proffer fee on developers. Provided that the market in which developers operate is competitive, this impact fee is likely to be passed onto users of housing services. This approach has the well-known advantage of being non-distortionary with respect to individuals' consumption decisions. Alternatively, balancing infrastructure and population can be achieved through setting an appropriate real property tax, though this approach introduces distortions into individuals' consumption decisions, leaving them with less aggregate consumption than with lump sum fees.

In addition, we find that legal and political restrictions on county officials' use of proffers and real property taxes have led them to the use of zoning in practice. Given the substantial fixed costs associated with infrastructure provision and the use of zoning, rising population leads to increased congestion before the number of households reaches a high enough threshold to make it feasible to open up a new land area. Ultimately, however, zoning remains an inefficient means to address localities' infrastructure and population issues. A more efficient solution would be to lessen restrictions on localities' use of proffers and their ability to raise revenue more generally.

Although Loudoun County, Virginia, has been used as a case study for calibration of our model, the framework set out in this paper should be broadly applicable to the problem associated with rising population in many areas of the United States. Indeed, the fixed cost aspect of infrastructure provision

combined with restrictions on localities' ability to raise revenue appear to be applicable to localities broadly.

REFERENCES

- Chatterjee, S., and G. Carlino. 2001. "Aggregate Metropolitan Employment Growth and the Deconcentration of Metropolitan Employment." *Journal of Monetary Economics* 48 (December): 549–83.
- Henderson, V. 1987. "General Equilibrium Modeling of Cities." In *Handbook of Regional and Urban Economics*, vol. II: *Urban Economics*. Ed. E.S. Mills. New York: New Holland.
- Loudoun County Office of Mapping and Geographic Information. <http://www.loudoun.gov/omagi/index.htm> (accessed December 23, 2003).
- Meeting with Loudoun County Officials (Ben Mays of Loudoun County Management Services and Clark Draper, Sean LaCroix, and Cindy Richmond of the Loudoun County Department of Economic Development), Leesburg, Virginia. August 2, 2003.
- Milligan, J. 2003. "Showdown in Loudoun." *Virginia Business* (April): 8–13.
- Sowell, T. 2001. "Property Rights." Townhall.com. <http://www.townhall.com/columnists/thomassowell/ts20010809.shtml> (accessed December 23, 2003).
- U.S. Census Bureau. "United States Census 2000." <http://www.census.gov/main/www/cen2000.html> (accessed December 23, 2003).
- Writ, Clay L. 1989. "Dillon's Rule." *Virginia Town and City* 24 (8): 12–15.